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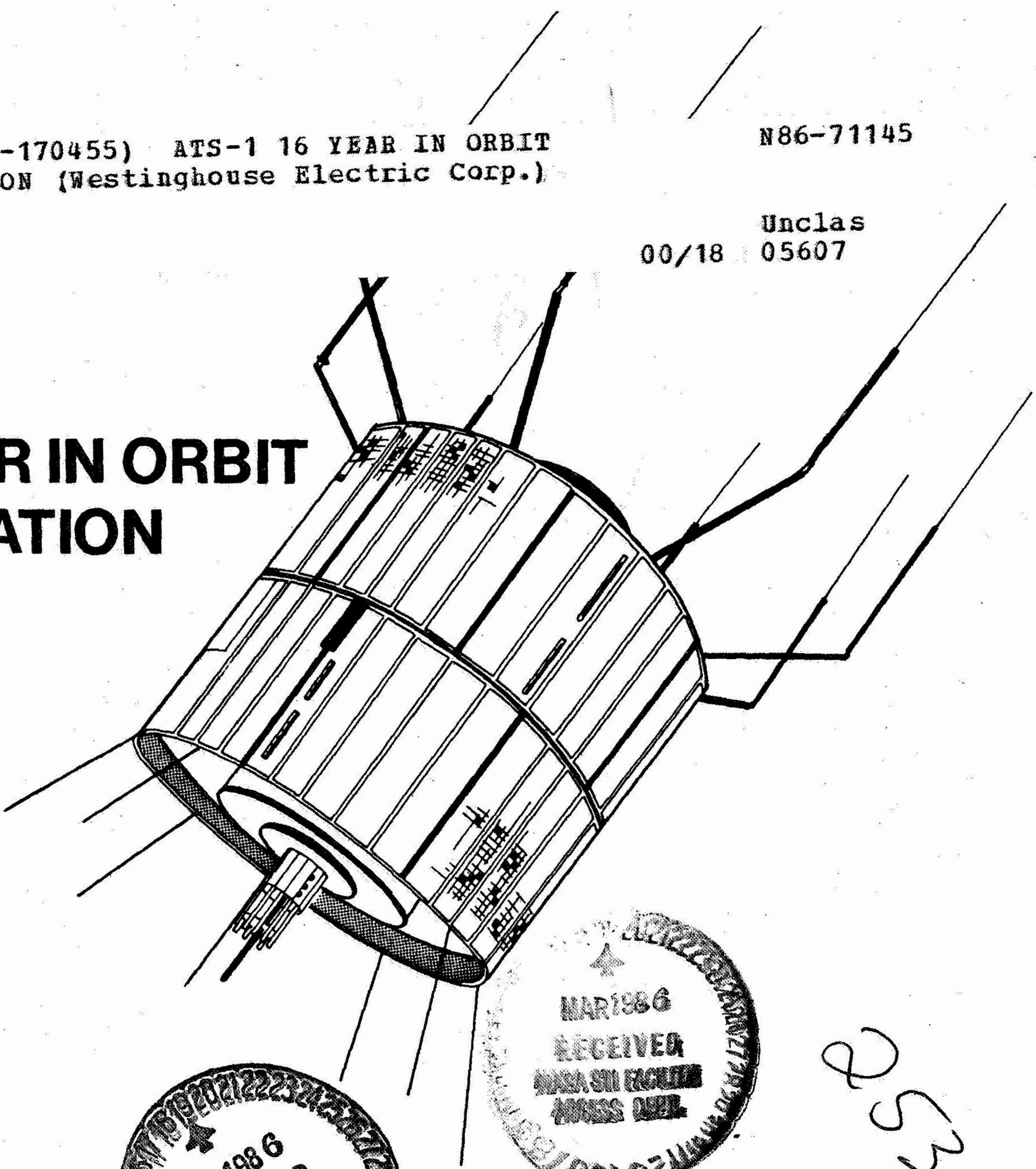

ATS-1
16 YEAR IN ORBIT EVALUATION

NAS 5-26188

MAY 1984

253.1

NASA
Goddard Space Flight Center
Greenbelt, Maryland 20771

NASA CR 170455

APPLICATIONS TECHNOLOGY SATELLITE 1

16 YEARS IN ORBIT

EVALUATION

May 1984

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Goddard Space Flight Center
Greenbelt, Maryland 20771

FORWARD

A series of tests were performed to check the C-band and Very High Frequency (VHF) Communications Systems and Power subsystem to determine the degradation of Application Technology Satellite 1 (ATS-1) satellite subsystems. The C-band tests were performed at the National Aeronautics and Space Administration (NASA) Ames Research Center (ARC) due to the availability of the C-band equipment. The power subsystem tests were performed at Goddard Space Flight Center.

The results of these tests were compared with the results obtained during the initial testing which was performed after ATS-1 was launched in December 1966.

The major spacecraft (S/C) subsystems are still functional, however, only the Very High Frequency (VHF) communications system is presently used since there is no C-band equipment at the ground stations.

In January 1982, maneuvers were performed to move ATS-1 from 148°W to a new location to serve the Territory of the Pacific Islands. After a series of slowdown/stopping maneuvers the S/C has reached its new location at 164°E. At this location, stationkeeping maneuvers will be required about one-sixth as often as at 148°W, reducing support requirements and fuel comsumption.

This report is submitted to Goddard Space Flight Center (GSFC) by Westinghouse Electric Corporation in response to NASA Contract Number NAS 5-26188.

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this report is to present the operational status of ATS-1 after over 16 years in operation. This is accomplished by comparing results of the End of Mission (EOM) tests recently performed with the series of similar tests performed after ATS-1 was launched in December 1966.

Throughout the years, additional testing was performed and the results documented in the ATS Technical Data Report dated March 3, 1967 and updated through July 20, 1970 which was distributed to the scientific/technical community. Other test results were documented in memos and letters with limited distribution, some of which are included as appendicies to this report.

1.2 BACKGROUND

The ATS-1 was launched on December 7, 1966 using an Atlas vehicle as the first stage and an Agena booster for the second stage. A Starfinder engine, developed by Jet Propulsion Laboratories, was used to provide the extra boost required to place the spacecraft (S/C) into synchronous orbit which occurred at second apogee.

During the first maneuver to erect the S/C spin axis, a wrong value was noted in the polarization angle. A check of the system determined that the A&B axial jets were displaced 180^{o}.

Orbit control maneuvers were successful and ATS-1 arrived at the designated on-station location with the desired drift rate and relatively low eccentricity.

The S/C contained experimental packages which would perform experiments in the following areas: meteorological, communications, S/C stabilization and envionmental measurements.

The performance of the on-board subsystems has been extremely satisfactory since launch. However as utilization of the S/C subysystem increased, there were certain anomalies and malfunctions which occurred. The current status of the subsystems are described below:

Power Subsystem

The Power subsystem is operational. The solar array is capable of full time operation of the VHF or C-band transponders, however, the C-band is currently not being utilized due to lack of ground station equipment.

C-Band Equipment

The C-band transponder #1 (6212/4120 MHz) suffers a 10 dB loss in gain after 10 to 15 minutes of operations. Transponder #2 (6310/4179 MHz) is operational and was used primarily for ranging.

T&C

The Telemetry and Command system is operational, however, the Sun Pulse Encoder (SC01) is left on continuously due to the difficulty in turning it on once it is commanded off.

Propulsion

The Propulsion System A is not used since it failed to produce a usable impulse during maneuvers in May 1979; it is presumed to be out of fuel. The Propulsion System B has been used for stationkeeping manuevers since the failure of System A. The system has essentially zero pressure and is assumed to have about 31 lbs of propellant (H_2O_2) left. It produces an extremely low impulse due to a leak-off of the nitrogen which was used for pressurization.

PACE

The PACE remains operational and is utilized for electronically positioning the VHF beam and C-band if necessary toward the earth.

VHF Transponder

The VHF transponder is the prime operational experiment and is performing with essentially no degradation since launch except for the power output, which has decreased approximately 3.5 dB.

EME

The Environmental Measurements Experiment and Nutation Damper are not operated.

Resistojet

The Resistojet failed, losing fuel on launch.

SSCC

The Spin Scan Cloud Cover Camera has failed, losing 60 dB of video gain during a test on 16 October 1972.

1.3 HIGHLIGHTS

The overall goal of the ATS mission was to advance the state of the art in the areas of communications, meteorology, environmental measurements and S/C stabilization. This goal was successfully achieved as hundreds of experiments were performed when NASA through the ATS program made the benefits of space communications accessible to the private sector. The response from foreign nations, government agencies, states, universities and corporations has been overwhelming. In many cases the experiments became a series of firsts in their particular fields/areas.

Experiments were performed in the areas of education, health, communications including aircraft and maritime, broadcasting, meteorology, time and frequency discemination, ranging and position fixing and data transmission.

A list of participants in the ATS-1 experiments include:

Foreign Nations: Australia, India, Italy, Japan, Netherlands, U.S.S.R., and United Kingdom

States: Alaska, Hawaii

Government Agencies: U.S. Navy, U.S. Air Force, U.S. Coast Guard, Department of Interior, Department of Transportation, National Institute of Allergy and Infectious Diseases, National Institute of Health, and National Oceanic and Atmospheric Adminstration (NOAA)

Universities: Duke University, Stanford University, University of Auckland N.Z., University of California, University of Hawaii, University of South Pacific, University of Washington and University of Wisconsin

Significant highlights include:

- o Transmission of real time television pictures of first splashdown of Apollo manflight which was transmitted around the world, 1967.

- o Transmission of over 11,000 WEFAX weather charts and 10,000 satellite earth pictures, 1968-1978.

- o Generation of Spin Scan Cloud Cover (SSCC) pictures for processing at Kasima, Japan and Wallops Island, Virginia. This was the fore- runner of the satellite pictures used by virtually all weather forecasters and viewed daily on U.S. TV weather reports.

- Demonstration of color television transmission between USA and Australia, Australia and Italy, Australia and Japan, Australia and India, and Australia and Spain.

- Demonstration of various maritime VHF data communications receive/transmit techniques with United Kingdom, Netherlands, Norway and Japan

- Performance of three station simultaneous ranging experiments to provide input for trilateration orbit determination program

- Transmission of college courses (physics, history and nursing education) and tutorial services between University of Hawaii and University of South Pacific, Jan-June 1972, Jan-June 1973.

- Presentation of medical conferences over "PEACESAT" network consisting of 12 nations, in conjunction with the University of Hawaii, 1971-1978.

- Presentation by the State of Alaska of an open forum for teachers in Alaska, Hawaii and South Pacific Territories.

- Conduction of daily medical conferences between doctors of National Institute of Health and health aides in remote Alaskan villages. Medical aides relayed patients symptoms to doctors who would prescribe treatment, 1972-1978.

- Development of the "MEDLINE" medical information retrieval system by National Institute of Health in conjunction with Stanford University, University of Alaska, and University of Washington, Jan-Dec 1973.

- Transmission of Electrocardiographs (EKG) from Hawaii to New Zealand and from Alaska to the University of Washington, Jan 1972-May 1973.

- Provision for communications between 100 research scientists in disease control in USA and Pacific areas.

- Provision for communication link between USA and USSR scientists during an experiment with atmospheric, sea and ice conditions, in Bering Sea, 1971.

- o Performance of two way communication tests involving airlines in normal flights and maneuvers to determine aircraft orientation effects and satellite communications, with the Department of Transportation/Federal Aviation Agency and airlines 1967-1968.

- o Performance of tests to determine effectiveness of voice communications between two aircraft and one aircraft and ground station in opposite hemispheres, Feb-March 1974.

- o Performance of numerous voice/data transmission experiments between various United Stated Coast Guard vessels and ground stations in Virginia, California and Australia 1968.

- o Experimentation with a transconnential interconnection to relay Education Television programs between South Pacific and east and west coasts of USA in conjunction with ATS-3, 1975-1978.

- o Relayed data from Antartica to NOAA data center in Nevada.

2.0 C-BAND COMMUNICATION SUBSYSTEM TESTS

2.1 BACKGROUND

The spacecraft C-Band tests were restricted to Effective Isotropic Radiated Power (EIRP) and Antenna Gain to System Noise Temperature Ratio (G/T) because of the limited ground station facilities and test equipment. The first series of tests was performed at the Rosman ground station in November 1980 just prior to closing the station. The second series of tests was performed in April and May 1982 using the Ames Research Center facility.

It should be noted that all values assigned to the spacecraft are dependent upon the calibration accuracy of the ground station. Thus some discrepancy may be expected among prelaunch, in-orbit, and EOM test results.

The test results are summarized in Tables 2-1 and 2-2 which include prelaunch and EOM values.

The prelaunch values shown in Tables 2-1 and 2-2 were obtained from the ATS Technical Data Report. The EOM values represent the best estimate of the true value, often derived from an average of several measurements.

TABLE 2-1. ATS-1 EIRP Test Results

	Pre-Launch[1]		Post Launch[1]			EOM EIRP		
	Tx Pwr (dBm)	Ant Gain (dB)	EIRP (dBm)	Ros 4/68 (dBm)	C.C. 5/68 (dBm)	Ros 11/80 (dBm)	ARC 4/82 (dBm)	TLM[2] 4/82 (dBm)
Repeater No. 1								
TWT 1	35.8	13.6	49.4		48.4		46.4	46.9
TWT 2	35.8	13.6	49.4		48.4		47.9	47.8
TWT 1 & 2	38.6	13.6	52.2		51.2[3]		49.5	50.2
Repeater No. 2								
TWT 3	35.8	13.6	49.4		49.2		46.5	46.4
TWT 4	35.8	13.6	49.4		48.7	46.7	46.5	45.8
TWT 3 & 4	38.6	13.6	52.2	51.4	51.8[3]		49.5	49.0

1 Technical Data Report Sections 7.1.1 and 7.1.2 (C.C. refers to the ATS ground station located at Cooby Creek, Australia)

2 EIRP calculated from S/C Tx telemetry (assuming Tx antenna gain = 13.6 dB)

3 Predicted EIRP for 2 TWT, assuming 0.2 dB combiner loss

TABLE 2-2. ATS-1 G/T Test Results

	Pre-Launch		EOM G/T			COMMENT
	G_{rs} (dB)	T_s (dB°K)	G/T (dB°K^{-1})	Ros 11/80 (dB°K^{-1})	ARC 4/82 (dB°K^{-1})	
Repeater No. 1	6.2	32.6	-26.4	-	-	Repeater No. 1 receiver failed
Repeater No. 2	6.2	32.6	-26.4	-28.6	-30.4	

2.2 SPACECRAFT EIRP

The C-band EIRP calculated values are shown in Table 2-3. Measurements were made with the spacecraft configured primarily in the Multiple Access (MA) mode with one and two Traveling Wave Tubes (TWT). The spacecraft EIRP was calculated from ground station measurements of received signal strength (P_{rg}) at the Rosman station, and from carrier-to-noise ratio (C/N) at the ARC station (refer to Appendix C for sample EIRP calculations). The S/C transmitter power output telemetry was recorded for each of the single TWT tests performed at ARC. The resulting power levels were used to compute the apparent S/C net antenna gain. This provided a cross check on the measurement accuracy since any deviations of the apparent gain from nominal indicates either change of gain (highly improbable) or an inaccurate measurement. On this basis, measurements of EIRP which result in an apparent antenna gain deviation of greater than ± 1.0 dB were excluded from further consideration.

The transmitter power output for 2 TWTs was inferred by adding the separate contributions (in watts), converting to dBm and subtracting the combiner loss of 0.2 dB.

As seen from Table 2-3, only a limited amount of data is available from the Rosman tests. This is because at the time the tests were performed the S/C was very close to the horizon mask of the station and most of the data was contaminated by antenna blocking.

2.3 SPACECRAFT G/T

The G/T of a receiving system is a figure-of-merit of the system performance. A method of measuring the in-orbit G/T has been developed (Appendix A) which requires a known signal level to be transmitted to the spacecraft coupled with accurate determination of the variation of the resultant spacecraft transmitted carrier output. The technique requires that a reference be established at the ground station while the S/C is transmitting maximum power output. This was accomplished for the Rosman tests by configuring the S/C in the Frequency Translation (FT) mode and radiating enough uplink power to drive the spacecraft into saturation. An alternative method is to configure the S/C in the MA mode to establish the reference level, then reconfigure the S/C to the Frequency Translation mode to complete the G/T measurement. The latter method was used for the ARC tests.

TABLE 2-3. ATS-1 EIRP EOM Test Data Summary

Gnd Sta/Date	S/C CONFIG		GND STA MEAS.		S/C Tx PWR			CALCULATED S/C PARAMETERS				
	MODE	TWT	C/N$_o$ (dB)	C/N$_o$ (dB-Hz)	S/C TLM (W)	S/C TLM (dBm)	from Prelaunch (dB)	EIRP (dBm)	from Prelaunch (dB)	from Tx TLM (dB)	Ant. Gain (dB)	from Prelaunch (dB)
ARC 4/13/82	MA	1	35	73.3	2.2	33.4	-2.6	46.4	-3.0	-0.4	13.0	-0.6
	MA	1&2	38	76.3		36.7	-2.1	49.4	-2.8	-0.7	12.7	-0.9
	WBDM	1&2	38	76.3		36.7	-2.1	49.4	-2.8	-0.7	12.7	-0.9
	MA	2	36	74.3	2.7	34.3	-1.7	47.4	-2.0	-0.3	13.1	-0.5
	MA	1&2	38	76.3		36.7	-2.1	49.4	-2.8	-0.7	12.7	-0.9
	MA	3	35	73.3	2.2	33.5	-2.5	46.5	-2.5	0	13.0	-0.6
	MA	3&4	38	76.3		35.7	-3.1	49.5	-2.7	+0.4	13.8	+0.2
	MA	4	36	74.3	1.7	32.2	-3.8	47.5	-1.9	+1.7	15.2	+1.6[4]
	MA	3&4	38	76.3		35.7	-3.1	49.5	-2.7	+0.4	13.8	+0.8
ARC 4/12/82	MA	1	37.5	76.8[1]	2.1	33.2	-2.8	49.9	+0.5	+3.3	16.7	+3.1[4]
	MA	1&2	39	77.3[1]		36.5	-2.3	50.4	-1.8	+0.5	13.9	+0.3
	MA	1&2	38	76.3		36.5	-2.3	49.4	-2.8	-0.5	12.9	-0.7
	MA	2	37	75.3	2.6	34.2	-1.8	48.4	-1.0	+0.8	14.2	+0.6
	MA	1&2	38	76.3		36.5	-2.3	49.4	-2.8	-0.5	12.9	-0.7
	WBDM	1&2	38	76.3		36.5	-2.3	49.4	-2.8	-0.5	12.9	-0.7
	MA	3	38	76.3	1.7	32.2	-3.8	49.5	+0.1	+3.9	17.3	+3.6[4]
	MA	3&4	40	78.3		35.1	-3.7	51.5	-0.7	+3.0	16.4	+2.8[4]
	MA	4	35	73.3	1.7	32.3	-3.7	46.5	-2.9	+0.8	14.2	+0.6
	MA	3&4	38	76.3		35.1	-3.7	49.5	-2.7	+1.0	14.4	+0.8
ROS 11/20/82	MA	4	-96[3]					46.7	-2.7			
	WBDM	4	-96[3]					46.7	-2.7			

1 Corrected for -3 dB polarization offset at ground station
2 Prelaunch Values: EIRP; 1 TWT = 49.4 dBm, TWTs = 52.2 dBm: Tx Ant Gain = 13.6 dB
3 Rosman received signal strength (dBm)
4 Data points deleted from further consideration due to excessive variance from nominal

Table 2-4 shows the G/T test data. In general, each test series results in several measurements of downlink carrier suppression from the reference level. The measured carrier suppression is used to compute the G/T as described in Appendix D. The resulting values are averaged together to obtain the best estimate of G/T.

2.4 CONCLUSION

2.4.1 Summary

- The EIRP from each TWT has degraded approximately 3 dB from prelaunch measurements.
- The prelaunch transmit net antenna gain of 13.6 dB is verified by EIRP measurements and S/C telemetry of transmitter power.
- The G/T of repeater No. 2 is approximately 4 dB less (-30.4 dB) than precited from pre-launch parameters.
- Repeater No. 1 is not operable as a transponder due to the failure of the C-band receiver.

2.4.2 EIRP Data Analysis

The measured EIRP values are highly correlated with the telemetry (TLM) values of S/C power output. This is readily apparent as shown in Table 2-3 where the measured EIRP is compared to the calculated EIRP based on TLM Transmit (Tx) data (column headed "from Tx TLM"). As shown, four data points exceeded the nominal by greater than $\pm$ 1 dB. These points were excluded from the final EIRP determination. The remaining 15 data points were sufficient to establish the present EIRP (from ARC data).

Reference to Table 2-1 shows that the measured EIRP has shown a gradual decrease with time. This is consistent with the observed behavior of similar type TWT amplifiers according to the TWT manufacturer (Hughes Aircraft Co.[1]).

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[1] Telcon; F.J. Kissel, Westinghouse; R.R. Eiermann, HAC; 14 June 1982.

Table 2-4. ATS-1 EOM C-Band G/T Test Data

	Pwr (dBm)	Downlink Carrier (dB)	Noise Sharing Correction Factor, (C.F.) (dB)	Calculated G/T (dB)
ARC 4/13/82		0 (ref)		
Rptr 1	56.5	-3	-0.2	-29.6
	55.5	-4	1.1	-29.6
	54.5	-5	2.3	-30.1
	53.5	-6	3.4	-30.2
			Avg	= -29.9
ARC 4/12/82		0 (ref)		
Rptr 2	56.5	-5	2.3	-32.2
	54.6	-6	3.4	-31.3
	53.5	-5	2.3	-29.1
			Avg	= -30.9
ROS 11/20/80		0 (ref)		
Rptr 1	51	-2.4	1.3	-28.7
	49.5	-3	0.2	-28.3
	48	-4	1.1	-28.1
			Avg	= -28.4
Rptr 2		0 (ref)		
	48	-4.5	1.8	-28.4

(1) C.F. is a correction factor which accounts for the noise power sharing of spacecraft transmitter output. Its value is a function of the carrier suppression (refer to Appendix A).

(2) Appendix D describes the calculation of G/T and presents a sample calculation.

(3) Tx Pwr corrected for -3 dB polarization off set at Ground Station Tx Antenna.

2.4.3 G/T Data Analysis

As shown in Table 2-2, the repeater no. 2 G/T was measured by ARC to be -30.4 dB (4.0 dB less than prelaunch predictions). This value is consistent with the Rosman measurements of -28.6 dB made approximately 1.5 years earlier. The two sets of measurements agree within 1.8 dB which is remakable when consideration is given to the fact that the measurements were performed at different ground station, separated in time and distance from each other.

It should be noted that the ATS-1 Flight Mission Plan lists the S/C receiver noise figure as 9 dB (vs. 6.2 dB in subsequent documents). If the prelaunch value was indeed 9 dB, than the predicted G/T would be -29.2 dB; a value which is nearly midway between the Rosman and ARC measurements.

3.0 VHF COMMUNICATIONS REPEATER TESTS

3.1 GROUND STATION EIRP VS. SPACECRAFT EIRP

The tests performed in May 1982 indicate that the VHF transmitter number I outout is approximately 4 dB lower than in 1970 and number 2 output is approximately 3 dB lower than in 1970. With both regulators and the waveform generator on, the combined output is approximately 3.5 dB below the 1970 level.

Figure 3-1 shows the reuslts of the May 1982 tests along with the graph from the 1970 ATS-1 and 3 Experimenter's Guide.

3.2 SPIN MODULTION TESTS

Figure 3-2 shows the peak to peak spin modulation amplitude vs. antenna beam position plots for the 1970 and 1982 tests.

Although the shapes of the curves are slightly different due to the number of points plotted in 1982, there appears to be no significant increase in spin modulation.

4.0 POWER SUBSYSTEM TEST

Table 4-1 is a list of telemetry commands together with the command number and amount of current drawn.

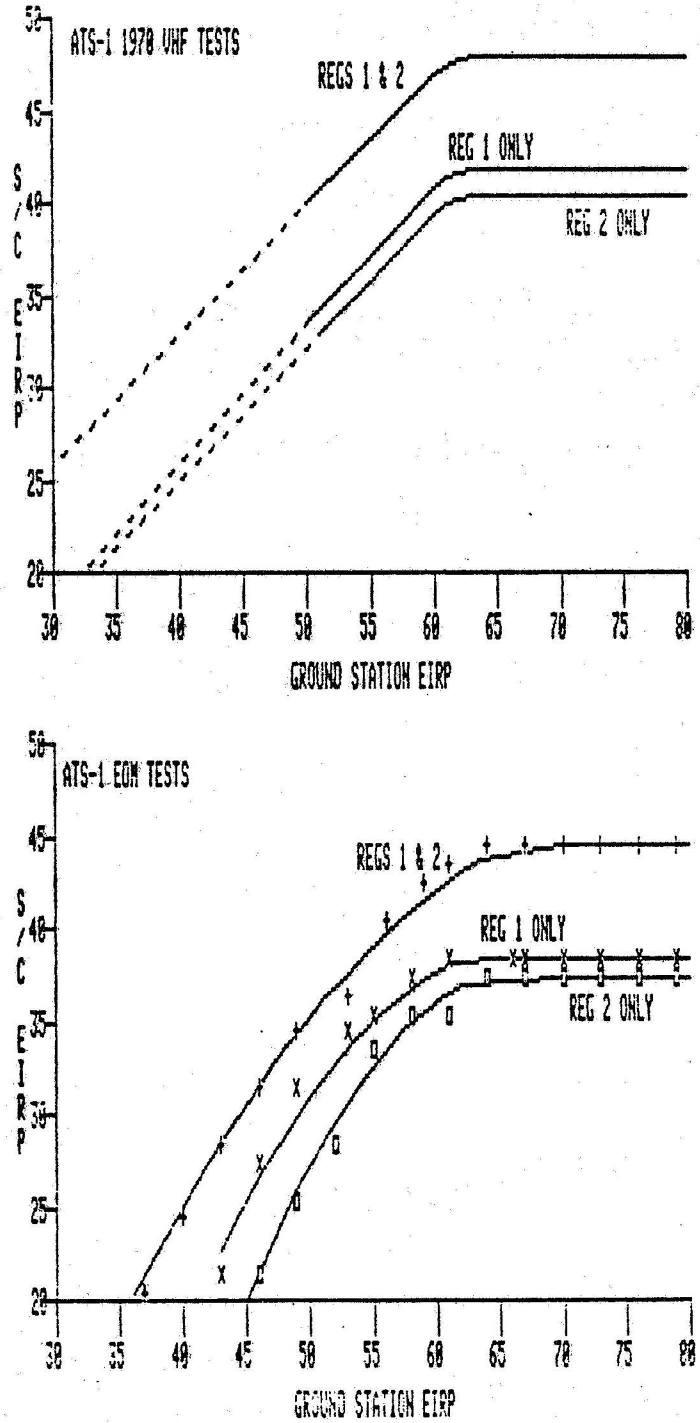
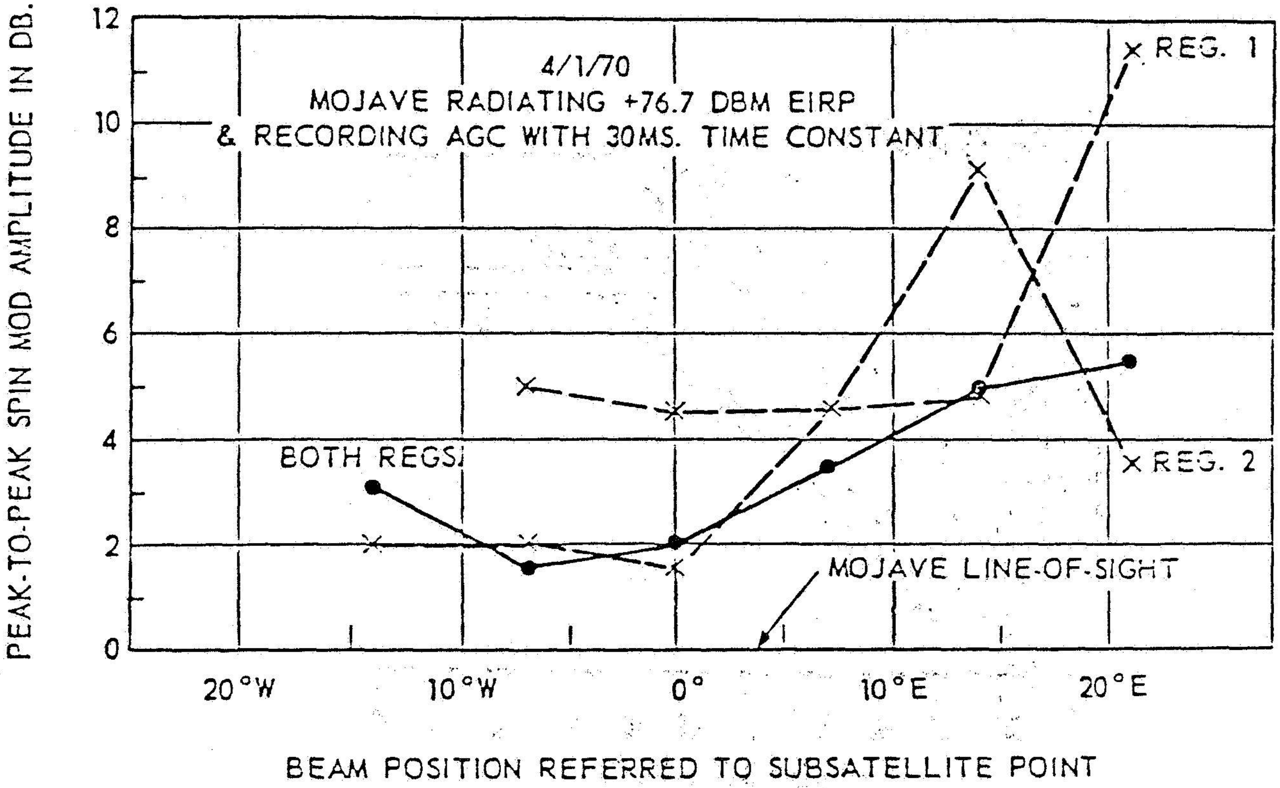

ATS-1 1970 VHF TESTS
REGS 1 & 2
REG 1 ONLY
REG 2 ONLY
S/C EIRP
GROUND STATION EIRP
ATS-1 EOM TESTS
REGS 1 & 2
REG 1 ONLY
REG 2 ONLY
S/C EIRP
GROUND STATION EIRP

FIGURE 3-1


PEAK-TO-PEAK SPIN MOD AMPLITUDE IN DB.
12
10
8
6
4
2
0
4/1/70
MOJAVE RADIATING +76.7 DBM EIRP
& RECORDING AGC WITH 30MS. TIME CONSTANT
REG. 1
REG. 2
BOTH REGS.
MOJAVE LINE-OF-SIGHT
20°W
10°W
0°
10°E
20°E
BEAM POSITION REFERRED TO SUBSATELLITE POINT

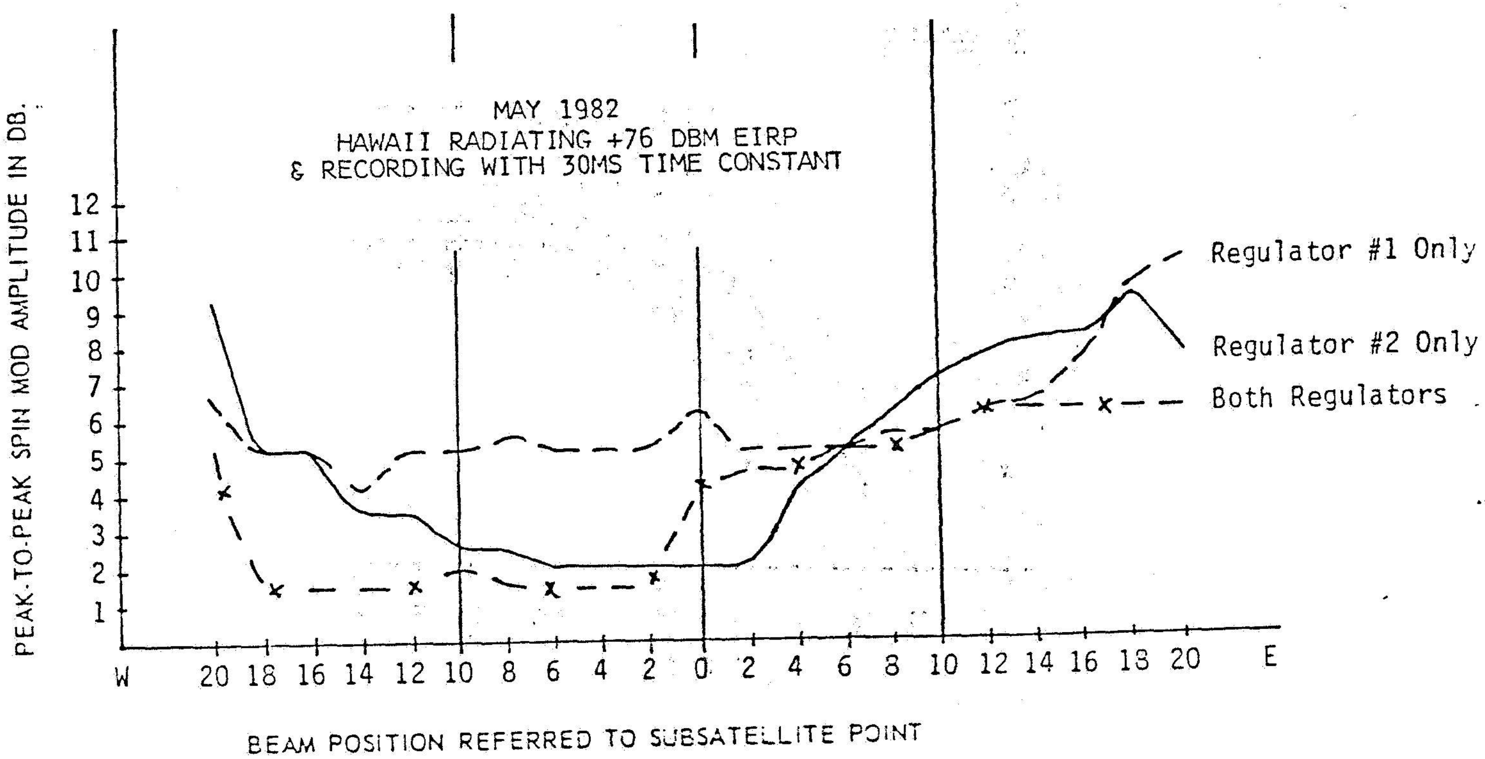

PEAK-TO-PEAK SPIN MOD AMPLITUDE IN DB.
MAY 1982
HAWAII RADIATING +76 DBM EIRP
& RECORDING WITH 30MS TIME CONSTANT
12
11
10
9
8
7
6
5
4
3
2
1
Regulator #1 Only
Regulator #2 Only
Both Regulators
W
20 18 16 14 12 10 8 6 4 2 0 2 4 6 8 10 12 14 16 18 20
E
BEAM POSITION REFERRED TO SUBSATELLITE POINT

FIGURE 3-2

Table 4-1. Current Comsumption

Command No.	Description	Prelaunch I(ma)	EOM I(ma)
147	Repeater 1 FT Mode ON	+194	+200
211	Repeater 1 MA Mode ON	+179	+200
357	Repeater 1 Wide Band Data Mode ON	+192	+200
270	Repeater 2 FT Mode ON	+194	+200
336	Repeater 2 MA Mode ON	+182	+200
060	Repeater 2 Wide Band Data Mode ON	+190	+200
022	Transponder 1 Fil. 1 ON	+121	+110
315	Transponder 1 Fil. 2 ON	+54	+50
001	TWT 1 & 2 High Voltage ON	+1447	+1400
164	Transponder 2 Fil. 3 ON	+121	+110
232	Transponder 2 Fil. 4 ON	+58	+50
126	TWT 3 & 4 High Voltage ON	+1432	+1400
376	VHF Regulator 1 ON	+1723	+730
251	VHF Regulator 2 ON	+1740	+1200
006	SSCC Regulator ON	+144	+190
124	Nutation Regulator ON	+179	+60
355	EME Payload Regulator ON	N/A	+230
341	UCLA ON	N/A	+10
256	Aerospace ON	N/A	+10
046	Rice ON	N/A	+10
234	Solar Cell ON	N/A	+10

5.0 OPERATIONAL AND ANOMALY/FAILURE HISTORY

5.1 OPERATIONS

The performance of various on-board electronics systems has been extremely successful. The operating times were logged daily and a total compilation from launch on December 7, 1966 through February 1983 is contained in Table 5-1. As noted, some units have been operating for over 16 years, over 4 times their expected operating life.

5.2 ANOMALY/FAILURE HISTORY

As utilization of the various S/C subsystems increased, anomalies and failures occurred. These anomalies and failures have been reported, investigated, tests performed and subsequently resolved. The history of these anomalies and failures are described briefly in subsequent paragraphs. A more detailed account may be obtained from the reference provided in each anomaly failure.

Hydrogen Peroxide, Reaction Control System

The Hydrogen Peroxide (H_2O_2) Reaction Control System is used in East/West stationkeeping and attitude correction maneuvering. Both systems (A and B) operated normally until the first eclipse period when a pressure leak was noted in both systems.

A series of tests was conducted (nutation experiments and thermal cycle tests). Results indicated that the leak was definitely in the form of a gas (N_2) leak not a propellant (H_2O_2) leak. Test results also indicated that the leak was not a result of any rupture of a weld or component. The prime suspect is that the pressure relief value may have caused the pressure leak.

The system is still being used for stationkeeping and attitude maneuvers using only the pressure built up by the natural instibility of H_2O_2. A detailed description is contained in the ATS Technical Data Report, Volume 1, Section 4.1.1.

TABLE 5-1
ATS-1 System Operations Log
December 7, 1966 through February 28, 1983

SYSTEM	TOTAL THRU FEB, 1983 HOURS
TRANSPONDER #1	7977
TRANSPONDER #2	17088
WIDE BAND DATA MODE	17898
F. T. MODE	18484
M. A. MODE	4157
T.W.T. #1	7667
T.W.T. #2	5589
T.W.T. #3	16871
T.W.T. #4	10051
PACE #1	328
PACE #2	140605
PHASE SHIFT DRIVER	140074
VHF REG #1	81761
VHF REG #2	79228
WAVEFORM GENERATOR #1	2314
WAVEFORM GENERATOR #2	112990
SSCC REG	9148
TLM XMTR #1	74228
TLM XMTR #2	139559
TLM XMTR #3	66423
TLM XMTR #4	1500
PCM ENCODER #1	17013
PCM ENCODER #2	141033
SUB-CARRIER OSCILLATOR #1	138223
SUB-CARRIER OSCILLATOR #2	
EME REG	63289
RESISTOJET	3
NUTATION SENSOR	59

Resisto Jet Thruster System

The ammonia fueled Resisto Jet Thruster System was installed on ATS-1 as an experiment for S/C east-west stationkeeping for eventual use on Geosynchronous Orbiting Environmental Satellite (GOES) 4 and 5.

The experiment was activated to determine the effective thruster outputs as a result of spin period change. Conflicting test results were obtained and a failure analysis was performed. The analysis consisted of a re-evaluation of flight data telemetry, a review of the S/C thermal vacuum test data, a chronological listing of events during experiment handling and the retesting of an engineering model.

It was concluded that during system rework, prior to S/C thermal vacuum testing, the pressure transducer was not sealed and possibly damaged causing abnormally high mass flows. The total firing time in the S/C thermal vacuum test was sufficient to deplete most or all of the propellant. For a detailed explanation, see the ATS Technical Data Report, Volume 1, Section 2.5.2.

Sub-Carrier Oscillator (SCO#1)

The Sun pulses from SCO#1 were used as a reference to determine the jet start angle used in a majority of S/C maneuvers and active nutation experiments. No problem occurred while commanding SCO#1 on and off until after five months. Then, some difficulty occurred at Rosman and later Mojave. In each case the command would get into the S/C command register and verification was received once the command was executed, however, SCO#1 would not turn on.

Changing the duration of the execute pulse from 50 MS to 200 ms did not correct the anomaly. Three command stations tried unsuccessfully to turn on SCO#1. The unit was finally commanded on and a decision was made to leave SCO#1 on indefinitely, since the power drain was approximately 150 mW which was insignificant. This decision was based upon the continuing need for SCO#1 as a source of real time data and the uncertainty of commanding the SCO on.

A study indicated that the anomaly is in the energization circuitry of SCO#1. A detailed description of this anomaly is contained in the ATS Technical Data Report, Volume 1, Section 4.1.1.

Antenna Electronics Thermal Effect

When both transponders were operating simultaneously with four TWTs for any extended time period, a drop in signal strength (-9dBm) was noted together with an increase in antenna electronics temperature. A series of tests was performed at the three ground stations, utilizing various combinations of TWTs while the received signal strength and antenna electronics temperature was monitored. Tests were performed in both summer and winter; a definite relationship was noted between the antenna electronics temperature and the sun's position with respect to the antenna, -23^{o} in winter and $+23^{o}$ in summer.

The summer test showed that the C-band beam antenna was undistored with a 10 dB loss in the main lobe and greater than 10 dB in the side lobes. This indicated that the ferrites in the phase shifter drivers were functioning correctly since only amplitude change was noted and not any change in phase shift.

The antenna temperature monitoring point is located near the antenna assembly and not near any particular component (i.e. stripline). The antenna electronics temperature telemetry indicated 110^{o}. It was felt that the stripline may have been 10^{o} to 20^{o} in excess of telemetry reading and thereby causing a substantial signal loss.

A detailed description of this anomaly is contained in the ATS Technical Data Report, Volume 1, Section 4.1.1.

Spin Scan Cloud Cover Picture Streaking

From launch, the Spin Scan Cloud Cover (SSCC) pictures appeared normal until mid May 1967 when streaking occurred. This streaking condition re-occurred and a test of SSCC ground equipment indicated that the equipment was operating normally. Telemetry obtained during the streaking periods indicated no abnormalities. However, a variation of 0.5 volts was observed in the d.c. baseline of the receive signal.

A relationship was made between picture streaking and battery bus voltage. Whenever heavy power loads exceeded the capacity of the Solar panels, then the S/C batteries became the primary source of power. Therefore whenever the batteries were severly depleated, any current demands would exceed the solar panel capabilities which caused the spin scan regulator to operate under a low voltage condition.

Tests were performed to verify streaking due to low battery voltage. A series of pictures was taken under various load conditions while the power system was monitored. Streaking was caused by a reduction in solar bus voltage which prevented the SSCC regulator from operating in its normal mode. Telemetry indicated that streaking was related to regulator voltage readings below 24 volts. Other tests were performed to insure that the sun angles were not the cause of streaking. To prevent any further occurrence of this condition, SSCC pictures were taken only when a low voltage condition did not exist.

For a detailed description, refer to the ATS Technical Data Report, Volume 1, Section 4.1.1.

APPENDIX A

In-orbit Measurement of G/T of A

Hard-limiting Transponder with AGC

The technique of measuring G/T is essentially one of measuring the system noise temperature. This is readily accomplished for a linear amplifier using well established techniques developed for measuring amplifier noise figure, i.e., measure the amplifier output power with no input, then measure the change in output with a known input. The problem becomes more complex if the amplifier contains a hard limiter which will limit on receiver noise. Some assumptions must then be made as follows:

1. The total output power is constant for all input levels
2. The intermodulation products due to front end noise are negligible

Using the above assumptions, the spacecraft noise power input, P_n, referred to preamp input is:

$$P_n = KTB \qquad (1)$$

where:

K = Boltzman's constant = $1.38\ (10)^{-23}$ w/°/Hz (-198.6 dBm/°/Hz)

T = Spacecraft system noise temperature (°Kelvin)

B = Spacecraft Noise Power Bandwidth

The spacecraft output power, P_{out}, is proportional to the signal power input, P_s, multiplied by the antenna gain, G, plus the noise power input, P_n;

$$P_{out} = P_{s\ out} + P_{n\ out} = C(P_s G + P_n) \qquad (2)$$

where:

C = constant of proportionality

P_s = Ground station EIRP (dBm) - path loss (dB)

For large P_sG (on the order of -70 dBm), P_n becomes negligible, and the total output power may be considered to be due to the signal input, P_sG. The signal power output, $P_{s\ out}$, may be observed and measured on a spectrum analyzer or a narrowband tuned voltmeter. As P_s is decreased, a decrease in $P_{s\ out}$ will occur, and $P_{n\ out}$ must then increase in order to maintain constant P_{out}.

From equation (2):

at high input power: $P'_{out} = P'_{s\ out} = C'P'_sG$ (2A)

and at low input power: $P_{out} = P_{s\ out} + P_{n\ out} = C(P_sG + P_n)$ (2B)

where C is a constant of proportionality and (') is used to indicate the high power condition.

From the above, since $P_{out} = P'_{out}$, we have:

$$P'_{s\ out} = P_{s\ out} + P_{n\ out} \tag{2C}$$

$$C'P'_sG = C(P_sG + P_n)$$

from which:

$$P'_sG = \frac{C}{C'}(P_sG + P_n) \tag{2D}$$

From equation (2C):

$$P_{n\ out} = P'_{s\ out} - P_{s\ out} \tag{2E}$$

Also, from (2B) and (2A):

$$P_{n\ out} = CP_n \text{ and } P'_{s\ out} = C'\ P'_sG$$

which substituting C and C' in (2D) gives:

$$P'_sG = \frac{P_{n\ out}}{P_n} \quad \frac{P'_sG}{P'_{s\ out}} \quad (P_sG + P_n)$$

Substituting for $P_{n\ out}$ from (2E) gives:

$$P'_sG = \frac{(P'_{s\ out} - P_{s\ out})\ P'_sG}{P_n\ P'_{s\ out}} \quad (P_sG + P_n)$$

dividing through by P'_sG gives:

$$1 = \frac{(P'_{s\,out} - P_{s\,out})}{P'_{s\,out}} \; \frac{(P_sG + P_n)}{P_n}$$

or

$$1 = (1 - P_{sr}) \; \frac{(P_sG + P_n)}{P_n} \qquad (2F)$$

where $P_{sr} = \dfrac{P_{s\,out}}{P'_{s\,out}}$

Expanding (2F) yields:

$$P_n = P_n - P_{sr}\, P_sG + P_sG - P_{sr}\, P_n$$

From which

$$P_{sr}\, P_n = (1 - P_{sr}) \; (P_sG)$$

or $$P_n = \frac{1 - P_{sr}}{P_{sr}} \; P_sG \qquad (3)$$

For the special case where $P_{sr} = 0.5$ (3 dB drop), $P_{n\,out}$ is equal to P_s out, and P_n is equal to P_sG as follows:

Equation (3) evaluated for $P_{rs} = 0.5$ becomes:

$$P_n = \frac{1 - 0.5}{0.5} P_sG = P_sG$$

or

$$P_n \Bigg|_{P_{sr} = 0.5\text{ dB}} = P_sG \qquad (4)$$

Substituting for P_n in equation (1) gives:

$$P_sG = KTB \text{ or } \frac{G}{T} = \frac{KB}{P_s}$$

Assuming 30 MHz spacecraft Noise Power Bandwidth:

$$G/T\ (\text{dB}) = -198.6 + 74.8 - P_s = -123.8 - P_s \qquad (5)$$

where:

P_s = Ground station EIRP (dBm) - path loss (dB)

The more general case of equation (5) becomes:

$$G/T\ (dB) = -122.6\ dB - 10 \log \frac{(1 - P_{sr})}{P_{sr}} - P_s\ (dB) \qquad (6)$$

Calculation of equation (6) is simplified by use of the nomogram shown in Figure A-1 (attached) which solves for the correction factor, C.F.;

$$C.F. = 10 \log \frac{(1 - P_{sr})}{P_{sr}} \qquad (7)$$

A basic assumption in the derivation just presented is that the signal-to-noise ratio is unchanged through the S/C limiter (essentially performing as a linear device with regard to S/N). Figure A-2 shows that the S/N transfer characteristic of a hard limiter is not linear(1). *This effect* has been used to modify the Correction Factor curve shown in Fiure A-1. The revised curve is presented in Figure A-3.

EXAMPLE

For synchronous altitude (ATS-3 subsatellite point at 105 west longitude), Rosman C-band transmitter:

$$P_s = P_{gnd}\ (dBm) + G_{gnd}\ (dB) - L\ (dB) \qquad (8)$$

where:

P_{gnd} = Rosman T_x power (dBm)

G_{gnd} = Rosman antenna gain = 58.5 dB

L = Path loss at 6301 MHz = 203.2 dB (includes 1.5 dB pointing loss)

Thus:

$$P_s = P_{gnd}\ (dBm) - 144.7\ dB$$

Substituting (7) and (8) into (6) gives the expression for the ATS-3 spacecraft G/T as a function of Rosman transmitter power:

$$G/T\ (dB) = -123.8 - C.F. - P_{gnd}\ (dBm) + 144.7$$

$$G/T\ (dB) = 20.9 - C.F. - P_{gnd}\ (dBm) \qquad (9)$$

Similarly, for the ARC we have:

$$G/T\ (dB) = 26.6 - C.F. - P_{gnd}\ (dBm)$$

(1) Davenport, Jr. Applied Physics, June 1953.

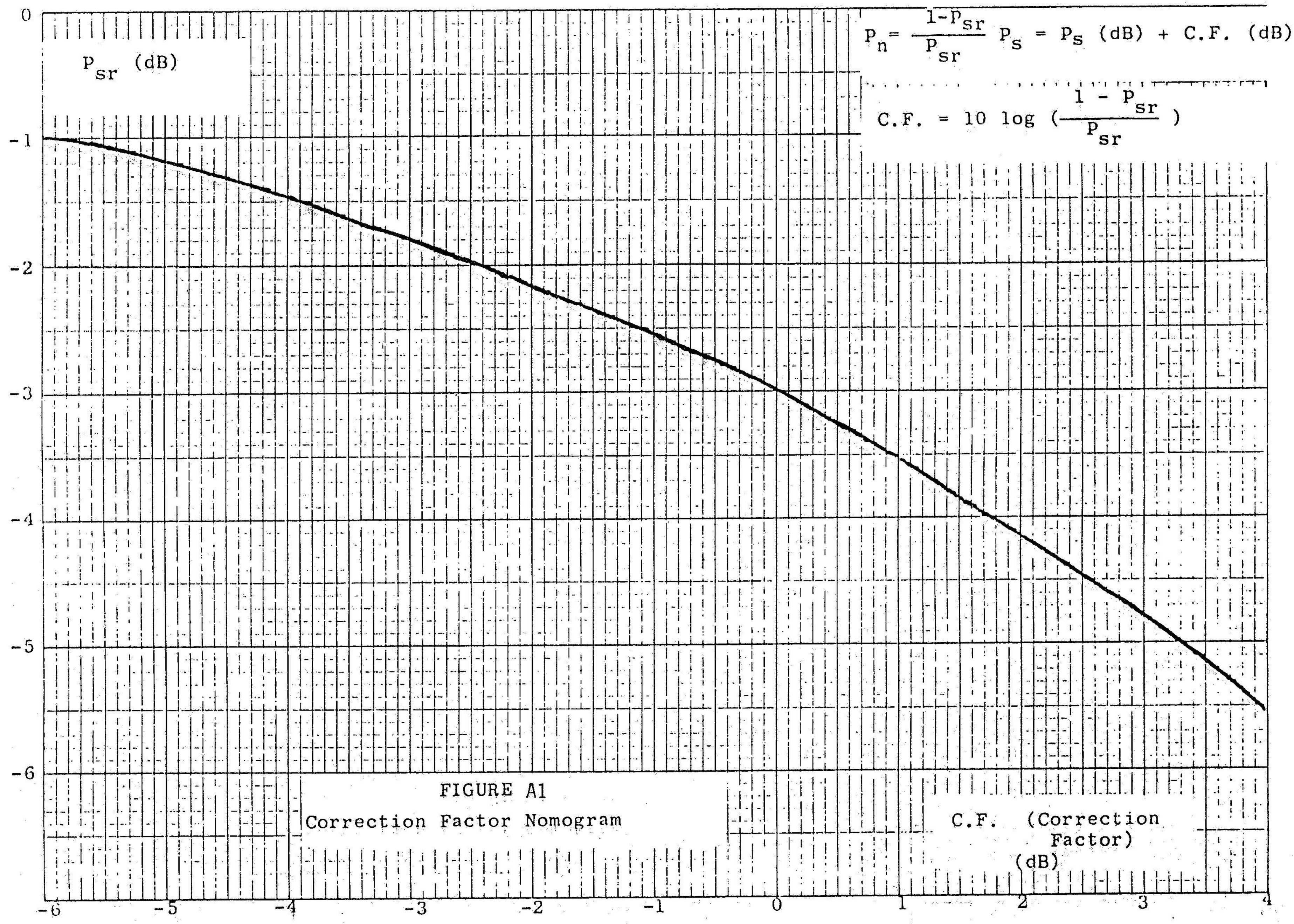
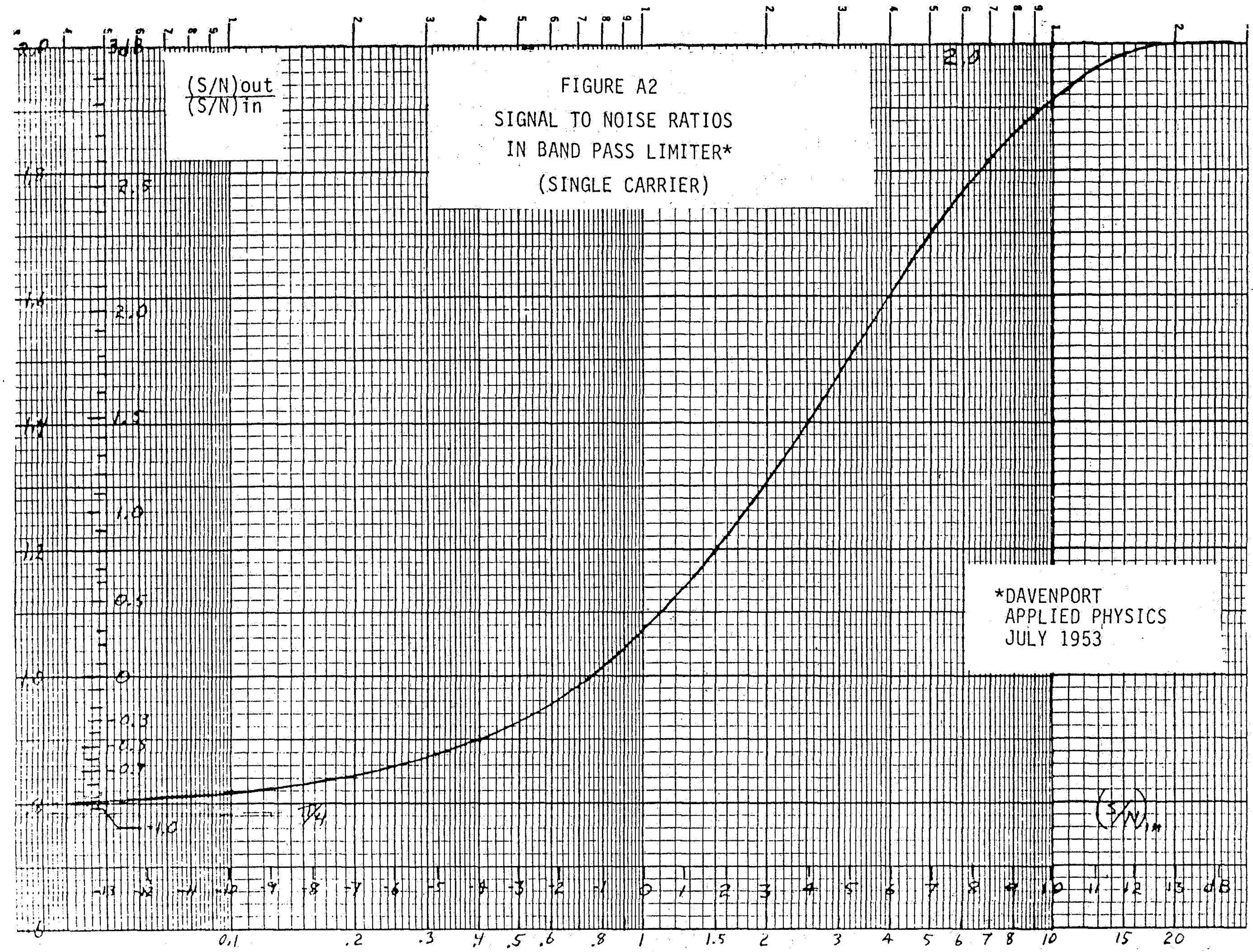


FIGURE A1
Correction Factor Nomogram


(S/N)out / (S/N)in
FIGURE A2
SIGNAL TO NOISE RATIOS
IN BAND PASS LIMITER*
(SINGLE CARRIER)
*DAVENPORT
APPLIED PHYSICS
JULY 1953
3dB
2.5
2.0
1.5
1.0
0.5
0
-0.3
-0.5
-0.7
-1.0
π/4
(S/N)in
dB
0.1
.2
.3
.4
.5
.6
.8
1
1.5
2
3
4
5
6
7
8
10
15
20

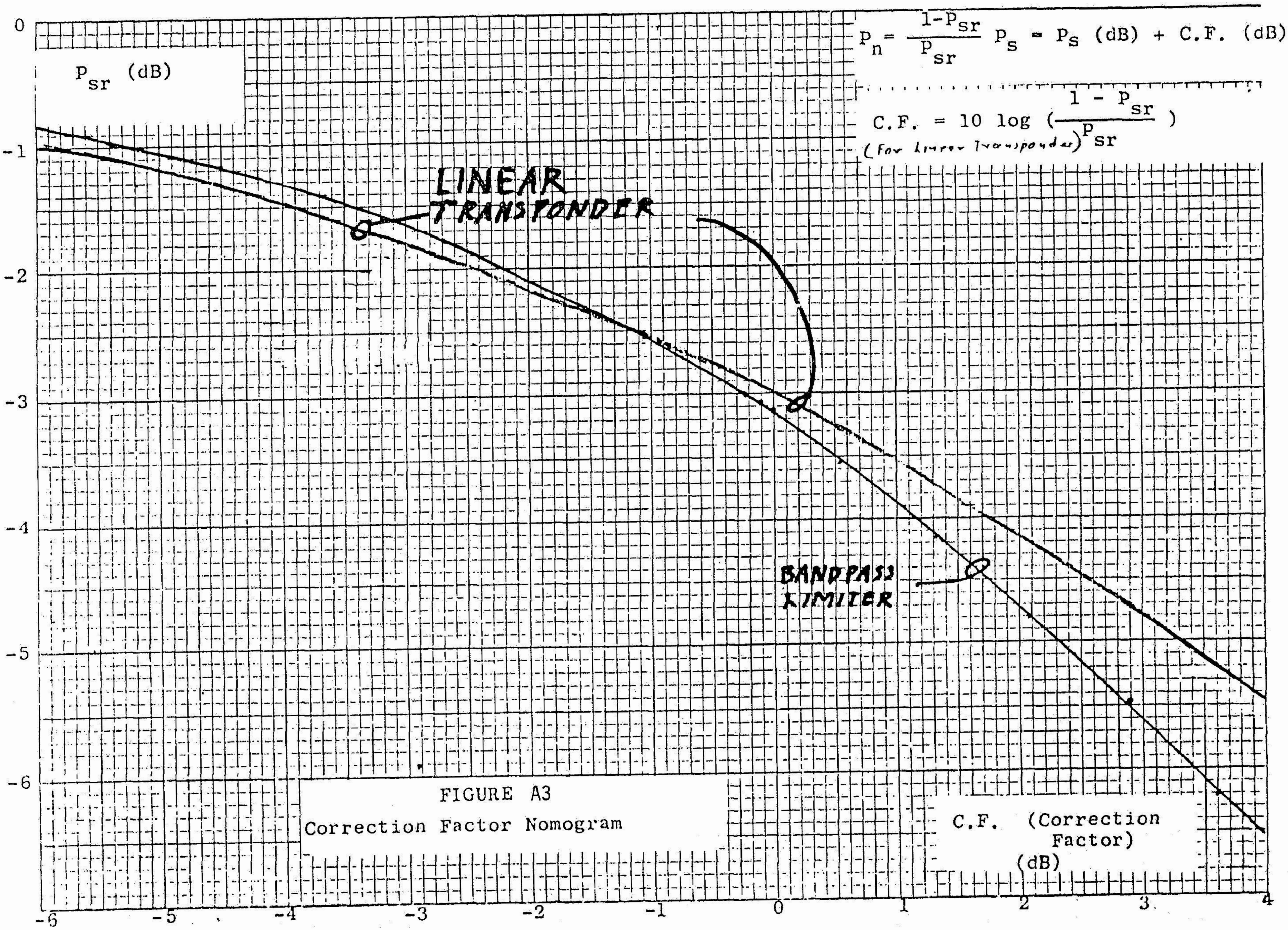


FIGURE A3
Correction Factor Nomogram

APPENDIX B

Calculation of System Noise Temperature from Specification and Prelaunch Measured Values

The spacecraft system noise temperature is dependent upon several factors; primarily the earth noise temperature, noise figure of the transponder and the receive losses of the transponder. The following formula is used to calculate the spacecraft system noise temperature referred to the preamp input.

General Formula

$$T_s = T_A + T_T + T(L-1) + L(T_R) \tag{1}$$

where: T_A = antenna noise temp

T_T = transmitter noise spill over into receiver band

t = physical temperature of coupling network

L = coupling network loss between antenna and receiver

T_R = LNA noise temperature

The spacecraft repeater prelaunch $T_R^{(1)}$ was measured to be $920^{\circ}K$[1]. The receive antenna losses are 1.6 dB (1.45:1 ratio). In orbit measurements show the temperature of the coupling network to be about $285^{\circ}K$ while $30^{\circ}K$ is a reasonable assumption for the degradation due to transmitter thermal noise out of band. The antenna sky noise is taken to be $20^{\circ}K$ when looking directly at the earth using the omni directional receive antenna.

[1] ATS Technical Data Report section 7.1.1, ref.

Using these values in (1) yields the spacecraft system noise temperatures referred to the electronics input. The G/T for the prelaunch parameters is determined by dividing the measured gain by the calculated system noise temperature.

From (1) for repeater no. 1

$$T_s = 290 + 30 + 285\ (1.12 - 1) + (1.12)(890)$$

$$= 1251^{o}K = 31.3\ dB^{o}K$$

$$G/T = 16.2 - 30.8 = -14.6^{o}\ dB\ K^{-1}$$

APPENDIX C

ATS-1 EIRP Calculation

(Rosman and ARC Measurements)

$$EIRP = C/N_o{*} - G/T + K + F.S. + S/C\ Ant.\ Pntg.\ Loss$$

<u>Rosman 11/20/80</u>

$$EIRP = C/N_o - 34.2 - 198.6 + 197.5 + 2.5$$
$$197.6 + 2.5$$
$$= C/N_o - 32.8 \text{ repeater 1}$$
$$- 32.7 \text{ repeater 2}$$

<u>Rosman from AGC</u>

$$EIRP = Prg - G + F.S. + S/C\ Ant.\ Ptg.\ Loss$$
$$= Prg - 57.4 + 197.5 + 2.5 = Prg + 142.6 \text{ rptr 1}$$
$$+ 197.6 + 2.5 \qquad 142.7 \text{ rptr 2}$$

<u>ARC 4/12-13/82</u>

$$EIRP = C/N_o - 19.2^{**} + (-198.6) + 198.2 + 2.7 \text{ rptr 1}$$
$$+ 198.3 \qquad \text{rptr 2}$$

$$= G/N_o - 26.9 \text{ rptr 1}$$
$$= C/N_o - 26.8 \text{ rptr 2}$$

* C/N_o corrected as required for ground station polarization mismatch.

** ARC G/T includes +0.8 dB correction for Noise Power Bandwidth.

APPENDIX D

ATS G/T Calculation

(Rosman and ARC Measurements)

Rosman 11/20/80

$$= -198.6 + 74.8 + 201.7 - 58.5 - Pg + 1.5 - C.F$$

201.8 (repeater 2)

$$= -Pg - C.F. + 20.9 \text{ repeater 1}$$

21.0 repeater 2

ARC 4/12-13/82

$$= -198.6 + 74.8 + 201.7 = 58.5 = Pg + 1.5 - C.F.$$

201.8 (repeater 2)

$$= -PG - C.F. + 26.6 \text{ repeater 1}$$

26.7 repeater 2

APPENDIX E

Acronyms and Abbreviations

AGC	Automatic Gain Control
ARC	Ames Research Center
CC	Cooby Creek Ground Station
C/N_o	Carrier Power to Noise Power Density Ratio
EIRP	Effective Isotropic Radiated Power (referred to an isotropic antenna)
EKG	Electrocardiograph
EME	Environmental Measurements Experiment
EOM	End of Mission
FT	Frequency Translation
GSFC	Goddard Space Flight Center
G/T	Antenna Gain to System Noise Temperature Ratio
MA	Multiple Access

NOAA	National Oceanic and Atmospheric Administration
PACE	Phased Array Control Electronics
PCM	Pulse Coded Modulation
PEACESAT	Pan Pacific Education and Communication Experiments
S/C	Spacecraft
SCO	Sub-Carrier Oscillator
SSCC	Spin Scan Cloud Cover
T&C	Telemetry and Command
TLM	Telemetry
TWT	Traveling Wave Tube
VHF	Very High Frequency
WBDM	Wide Band Data Mode